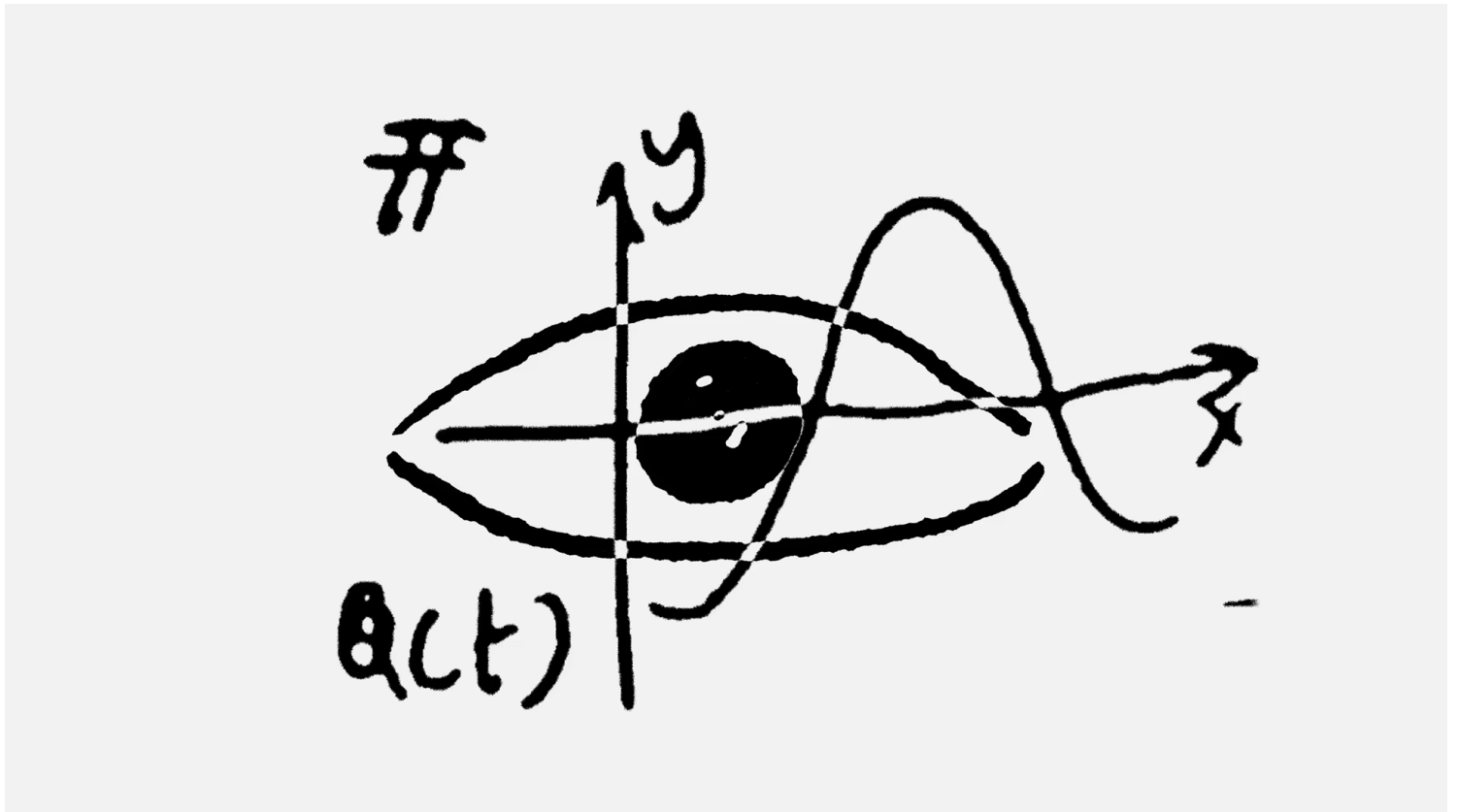


EDUCATION

Math Is Personal

How one professor changed the culture of mathematics for his students

By Jessica Nordell



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The mathematician Federico Ardila-Mantilla grew up in Colombia, an indifferent student but gifted in math. He was failing most of his classes at his high school in Bogotá when someone suggested he apply to MIT. He had not heard of the school. To his surprise, he got in, and he went on scholarship. Mathematically, he did well. One of his professors—an acid-tongued theoretician known to compare his audience to a herd of cows—routinely tucked “open” math problems into homework assignments, without telling the students. These had never

been solved by anyone. Ardila solved one. He went on to receive his bachelor's and Ph.D. in math from MIT.

But his academic experience was also one of isolation. Part of it had to do with his own introversion. (An outgoing mathematician, the joke goes, is someone who looks at your shoes when talking to you instead of their own.) Part of it was cultural. As a Latino, he was very much in the minority in the department, and he did not feel comfortable in American mathematical spaces. No one had tried to explicitly exclude him, yet he felt alone. In math, collaborating with others opens up new kinds of learning and thinking. But in his nine years at MIT, Ardila worked with others only twice.

At the time, he didn't clearly see the problem. But later, as a professor, he noticed a pattern. Ardila's Black, Latino, and women students who went on to Ph.D. programs also told stories of isolation and exclusion, of trying to join a study group but finding that no one wanted to work with them. Indeed, research has shown, STEM students from ethnic and racial minorities often feel isolated on university campuses, and women STEM students find themselves routinely denigrated and underestimated, even when outperforming men.

Mathematics as an academic field is notoriously homogenous—mostly White or Asian and male—and though mathematicians are not seen as the epitome of masculinity, the culture is macho and aggressive. “Abusive language,” Ardila told me, “is completely normalized.” Although the elders of the field set this tone, the tradition is carried on by younger professors. Andrés Vindas-Meléndez, one of Ardila's former grad students, described to me an experience he had as an undergraduate at UC Berkeley when he asked an adviser for a signature on the forms needed to declare the mathematics major. “You're not going to be a mathematician,” the adviser had told him. As Vindas-Meléndez was walking out the door, the adviser said, “Don't embarrass yourself. And don't embarrass the department.”

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To Ardila, now a professor at San Francisco State University, the problem was significant: 60 percent of his students come from ethnic minority groups. Nearly half are first-generation college students. So Ardila decided to do what mathematicians do when faced with a huge conundrum: begin by focusing on a smaller problem. He set out to create, in his own classroom, a new kind of math environment.

First, Ardila had to reimagine what math culture could be. To avoid perpetuating macho aggressiveness and instead make the classroom a place where students would feel comfortable and supported, he devised a class agreement. Students were asked to commit to taking “an active, patient, and generous role” in their learning and that of their classmates. Achieving the right tone also meant rethinking how he spoke about math. Mathematicians frequently use phrases like *It's obvious* or *It's easy to see*, which can be profoundly discouraging for a student who does not immediately find a concept simple. In math, grappling with extremely difficult problems is part of the learning process. “A challenging experience,” Ardila told me, “can easily become an alienating one.” It's especially important to make sure that students are not discouraged during early challenges—what's hard to see now may become easier in time. He struck this typically demoralizing math language from his teaching.

Other changes followed. Ardila observed that only a few students would speak in class, so after he posed a question, he asked to see three hands before calling on anyone. The first hand usually shot up quickly, and sometimes the second. Eventually, a third hand would rise, tentatively. Then Ardila would ask students to share their ideas in reverse order. They eventually caught on, he told me, but in the process, they understood that all their voices were welcome and encouraged. Classes that began the semester with only a sliver of vocal participants would end with everyone talking.

The End of Bias

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“Many students feel pressure to leave their true selves at the door,” Ardila said, especially if they are from groups not usually visible in the field. So he found ways to invite them to bring more of themselves to math. He would play music to make the classroom more comfortable. Then he invited students to bring in music of their choice. In one calculus session, he assigned a classic challenge—identifying the optimal shape of a can to maximize its volume and minimize the materials used to make it—and asked people to bring a can of food from home to explore the problem. Some students returned with items that reflected their cultural backgrounds: cans of refried beans or coconut milk. Others brought in trendy coconut waters and juice.

From a materials standpoint, the wide, short cans of refried beans were the most efficient, students discovered, while coconut-water cans, which tended to be tall and thin, looked larger but were the least efficient. The exercise prompted a spirited discussion about cultures and foods and competing values in the marketplace. Ardila realized that he didn’t need to demand that students discuss their identities by, say, writing a word problem about refried beans. He could simply make a conversation possible, and then listen with curiosity and openness. Slowly, as students shared, a mathematical community began to form.

This community expanded when Ardila developed a collaboration between San Francisco State and the elite Universidad de los Andes in Colombia. He conducted joint classes in English via video. Each group was impressed with the other—the Los Andes students noted the dedication and work ethic of the SFSU students, while they in turn were inspired by the advanced math background of the Los Andes class. The final projects were done in pairs; the collaborations took place, as Ardila said, “in the whole Spanish-English spectrum.” Many of the U.S. students were Latino and had spoken Spanish only with their families; now they were learning to communicate about advanced math in Spanish, too. The international partnerships, Ardila noted, proved the most fruitful, another instance of differences being generative in an atmosphere of genuine learning.

To further solidify this nascent community, Ardila created a math conference in Colombia, which has grown to include people from 20 countries, most of them in Latin America. Experts and students work on problems together, share open problems, cheer one another on, and even dance salsa together. “Math is human,” said Andrés Vindas-Meléndez, who now considers Ardila a mentor.

In typical school settings, students who can do well on tests or solve problems quickly are labeled the best. Ardila offered other ways to succeed, assigning open-ended problems, which are closer to the actual practice of science. Students who might not

have performed well in the past revealed new strengths. “I see students who got low scores on tests,” he told me, but when they’re deeply and personally involved in the mathematics, “they’re able to really show a very different kind of work.”

For a final project in Euclidean and non-Euclidean geometry, for instance, one student of Mexican and Indigenous descent wanted to learn how his ancestors did math. The student built a replica of the Chichén Itzá temple of Kukulcán, the Mayan snake god. The temple was designed so that at the equinox, the light and shadow cast by the setting sun appears like a serpent slithering from the top of the stairs to the bright snake head at the bottom. The student uncovered the math needed to re-create the structure, complete with the undulating light of the serpent. The project was, Ardila said, of a noticeably higher caliber than the student had demonstrated before. “When students see themselves reflected in the curriculum, it qualitatively changes the kind of work they can do. It’s really moving.”

Math, after all, is personal, emotional. “Anybody who does mathematics knows this. I just don’t think we have the emotional awareness or vocabulary to talk about this as a community.”

Much research suggests that feeling accepted and having a sense of belonging—the hallmarks of inclusion—helps people persist through difficulty and boosts their achievement. It also helps them stay motivated to remain in their field.

In the case of Ardila’s students, inclusion has had an astonishing impact. Of the 21 students in the first joint math class with the Universidad de los Andes, 20 went on to get graduate degrees in math and related fields. Half of these students were from San Francisco State. Fifteen went on to seek Ph.D.s in math and related fields, and 14 are already professors. This would be an astounding number even at an elite university, but at a non-Ph.D.-granting state school such as SFSU, it’s unprecedented. Many of the students originally had no intention of pursuing math Ph.D.s. Of the 200 students who have participated since the program’s founding, 50 have gone on to get doctorates in math. Almost all the U.S. participants are women or from historically underrepresented ethnic-minority backgrounds.

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To create cultures that don’t systematically exclude people, it’s important to be comfortable acknowledging differences. [A recent study](#) of nearly 700 college students found, in fact, that acknowledging differences affects perceptions of bias and may even help student achievement. The students, assigned to an online chemistry,

physics, or math class, were presented with one of two teaching philosophies, or a control.

One set of students, presented with a “color-blind” teaching philosophy, heard an audio welcome message in which the instructor explained that it was important for them to keep in mind the ways they were similar to one another, and that this would promote collaboration and learning. They also received a syllabus that further explained that the classroom was to be a place where students can flourish, and that keeping similarities in mind would improve empathy and interactions.

Another set of students, assigned the “multicultural” teaching philosophy, encountered a different welcome message, asking them to keep in mind their differences; their syllabus asserted that considering differences would foster better interactions. When presented with the “acknowledging differences” philosophy, students of color, including Black, Latino, East Asian, South Asian, Native American, Middle Eastern, and Native Hawaiian students saw the instructor as less biased than when he advocated for focusing on similarities. They also performed better on a comprehension quiz than those in the “color-blind” group. White students, by contrast, saw the instructor as more biased when he acknowledged differences, and least biased when he presented a “color-blind” philosophy.

Fostering an inclusive environment also requires leaders to set the right tone. Mekka Okereke, a director of engineering who is a Nigerian American, was in a meeting where people were discussing an outgoing email. Someone chimed in, with an attempt at humor, that the email “should sound like our company sent it, not like Nigerians sent it.” The room went silent as others looked at Okereke, unsure of how to react. He took a deep breath and said, “Hi. Mekka here. I run all our email and notifications systems. Too bad, Nigerians are sending it anyway.” He defused the situation and made it clear that hurtful comments would not be tolerated. But, he added later, although he doesn’t mind using humor and advocating for himself, he shouldn’t have to. This was a crucial moment in which a teammate could have stepped in to address the remark.

Of course, the extent to which people want to bring their identities to work or school can vary from person to person. And even in a culture that welcomes this, acknowledging differences without making a person feel like an exotic specimen can be difficult. A recent college graduate told me about a writing class he had taken, in which the instructor repeatedly referred to the fact that he, the student, was Korean American, and frequently suggested he write about being Korean American. This excessive attention felt alienating to the student: He did not especially want to write about his identity. He had not even mentioned it in class.

But Ardila’s lesson with the food cans is an example of how to go about welcoming difference with sensitivity and care. He didn’t force it or demand that people share

when they weren't comfortable. Instead, he created a space in which people were able to express their full identities, signaling that they were welcome. Through language, through class policies, through an environment of respect, curiosity, and mutual encouragement, he communicated that everyone had room to succeed. He did not push people to divulge their experiences, but was open to it and listened with respect and attention when they did.

This article is adapted from Jessica Nordell's new book The End of Bias: A Beginning.

The End of Bias

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